MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

ETM4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(TE)

03 MARCH 2020
09:00 a.m – 11:00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 6 pages with 4 Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Light travels from air into an optical fiber with an index of refraction of 1.44.

(i) If the angle of incidence on the end of the fiber is 22°, what is the angle of refraction inside the fiber? [4 marks]

(ii) Sketch the path of light as it changes media. [2 marks]

(b) Light traveling through an optical fiber (n=1.44) reaches the end of the fiber and exits into air.

(i) If the angle of incidence on the end of the fiber is 30°, what is the angle of refraction outside the fiber? [3 marks]

(ii) How would your answer be different if the angle of incidence was 50°? Will the light exit the fiber or not? If the answer is no, why? [2 marks]

(c) Consider a step index fiber with 25 μm core radius, a core index $n_1 = 1.48$, and $\Delta = 0.01$.

(i) If λ = 1320 nm, what is the value of V parameter and how many modes propagate in the fiber? [3 marks]

(ii) Will this fiber be single mode when the operating wavelength is λ = 1320 nm? [4 marks]

(iii) What percent of optical power flows in the cladding? [2 marks]

(iv) If the core-cladding difference is reduced to $\Delta = 0.003$, how many modes does the fiber support and what fraction of the optical power flows in the cladding? [5 marks]

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Question 2

The longitudinal modes of a gallium arsenide (GaAs) injection laser emitting at a wavelength of 0.81μm are separated in frequency by 220GHz. If we consider the following:

(a) The gap between the laser source and the fiber is filled with air.
(b) The refractive index of gallium arsenide is 3.4
(c) GaAs injection laser has an optical cavity of width 120 μm
(d) Same mirror reflectivity at each end of the optical cavity.
(e) The current threshold is 70mA
(f) The loss coefficient per cm is 18
(g) The internal quantum efficiency of the laser is 95%.
(h) Assume that the current is confined to the optical cavity.
(i) Number of photons per second that generated by this laser source is 500.
(j) Consider 60% of number of photons per second generated by the laser in section (i) are incident on a PIN photodiode.

Then, determine:

1. The length of the optical cavity. [3 marks]
2. The number of longitudinal modes supported within the structure. [2 marks]
3. The Fresnel reflection loss. [2 marks]
4. The threshold current density. [3 marks]
5. The gain factor for the device. [4 marks]
6. The differential quantum efficiency of the device. [3 marks]
7. Number of injected electrons per second. [3 marks]
8. The quantum efficiency of the PIN photodiode, in case the number of electrons generated by this PIN photodiode is 250. [3 marks]
9. Calculate the responsivity of the PIN photodiode. [2 marks]

Continued...

Question 3

(a) What is the peak emission wavelength from double heterojunction LED, which has power generated internally 20mW at a drive current of 147mA? Consider that, the radiative recombination lifetimes of the minority carriers are five times than the nonradiative of recombination lifetimes of the minority carriers in the active region.

[7 marks]

(b) Consider that avalanche photodiode (APD) has a quantum efficiency of 60% at 0.98μm. When illuminated with radiation of this wavelength it produces an output photocurrent of 20μA after avalanche gain with a multiplication factor of 300.

(i) Calculate the received optical power to the device. [6 marks]

(ii) How many photons per sec does this correspond to? [2 marks]

(c) Consider that, the quantum efficiency of PIN photodiode (InGaAs) is 75%, and incident optical power of wavelength 1550nm is 350nW. The dark current operating at this wavelength is 2.5nA and the load resistance is 4kΩ, and the post detection bandwidth of the receiver is 200MHz.

Under absolute Temperature T=293K, find quantum (shot noise), bulk dark current noise and the thermal noise. [10 marks]

Continued...

Question 4

(a) An intensity-modulated analog fiber-optic link employs a laser transmitter which couples a mean optical power of 0dBm into a multimode optical fiber cable. The cable exhibits an attenuation of 2 dB/km with splice losses estimated at 0.25 dB/km. A connector at the receiver end shows a loss of another 2dB. The PIN photodiode receiver has a sensitivity of –30dBm for a carrier to noise ratio (CNR) of –50 dB with a modulation index of 0.5. A safety margin of 10dB is required. The rise times of the laser source and PIN diode are 1.5ns and 2.5ns, respectively, and the intermodal and intramodal rise times of the fiber cable are 9ns/km and 2ns/km, respectively.

(i) What is the maximum possible link length without repeaters?

[9 marks]

(ii) What is the maximum permitted 3-dB bandwidth of the system?

[6 marks]

(b) A dense wavelength division multiplexing (DWDM) optical communication system operating at 1.55μm should be installed between Seremban and Melaka (80 km). The link contains two amplifiers, one booster amplifier was deployed with gain equal 18dB, and one pre-amplifier, with gain of 12dB. The receiver sensitivity for each wavelength channel in the fiber in Melaka is -16.6dBm and the optical fiber has an attenuation of 0.2dB/km. In addition, an optical filter deployed in front the receiver with loss of 2 dB, and 0.3dB loss encountered by each channel passing through a multiplexer and another 0.3dB loss at De-multiplexer.

Calculate the required minimum transmission power for each wavelength channel (allowing a power margin of 10 dB).

[10 marks]

End of Page

Appendix I

Physical constants:

vacuum permittivity

$$\varepsilon_0 = \frac{10^{-9}}{36\pi} = 8.85418 \times 10^{-12}\ F/m$$

Vacuum permeability

$$\mu_0 = 4\pi \times 10^{-7} = 1.25663 \times 10^{-6}\ H/m$$

Boltzmann constant

$$k_B = 1.38066 \times 10^{-23}\ J/K$$

vacuum intrinsic (wave) impedance

$$\eta_0 = 120\pi[\Omega]$$

elementary charge

$$q = 1.60218 \times 10^{-19}\ C$$

$$1eV = 1.60218 \times 10^{-19}\ J$$

Plank's constant

$$h = 6.62617 \times 10^{-34}\ J - s$$

Speed of Light

$$c = 2.998 \times 10^{8}\ m/s$$